The Pump Jack Advantage

Sponsored by the water4 Foundation

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BAE 4023

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Mission Statement

The Pump Jack Advantage Team is providing a pump jack system that can be used by handicapped people and small children without assistance from others. This will give people who have not been able to access water an easier avenue. Ultimately, the goal is for the system to be the “go to” system for manually pumped water wells.

Background

Water scarcity is a growing problem across the world. Some underdeveloped countries may have an adequate supply of water that is not easily accessible or may not be economically feasible to obtain. The Water4 Foundation is a non-profit organization that strives to provide these countries with the necessary equipment to obtain clean water. They will not only provide these citizens with the necessary equipment to drill and pump water wells, but they also instruct these individuals how to operate and repair the equipment so that they can become self-sufficient. “The Pump Jack Advantage” senior design group was formed to create a pump jack design that can be operated by handicap and young individuals in underdeveloped countries. Water4 set a budget for the materials of the pump jack to be under a $150. The system must also be able to be built, repaired, and operated with the materials available in the specific area. Water4 provides locals with specialized tools shipped over in a container. These tools include general hand tools, a welder, grinders and a small plasma table.

Patent Searches

The group researched any possible patent conflicts that involved the related designs to our pump jack. No conflicts were found as most mechanically advantaged pump jacks were expired by the early 1900s. The figure on the left shows a pump jack that uses a simple lever arm but it had several complex components that would be difficult to machine or repair; the design was not considered. The figure on the right illustrates a good example of turning rotational motion to linear motion. Both examples were too complex to consider.

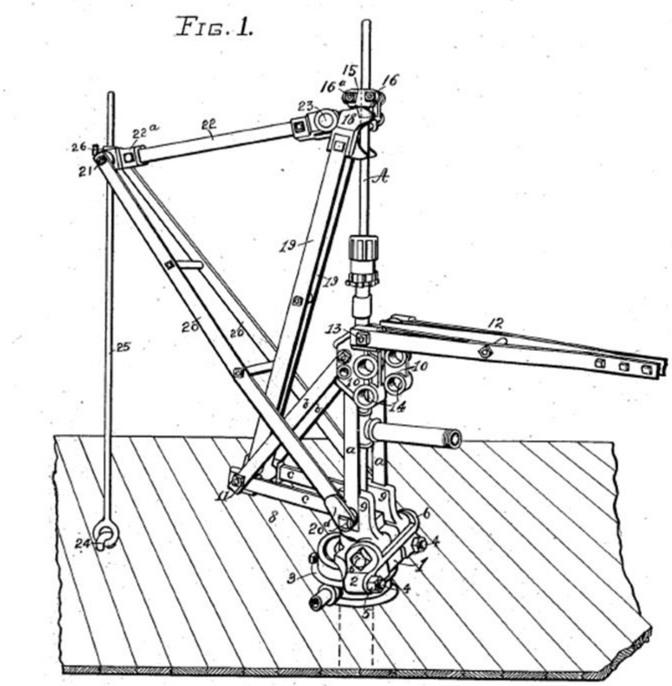


Figure 1: Complex Pump Jack

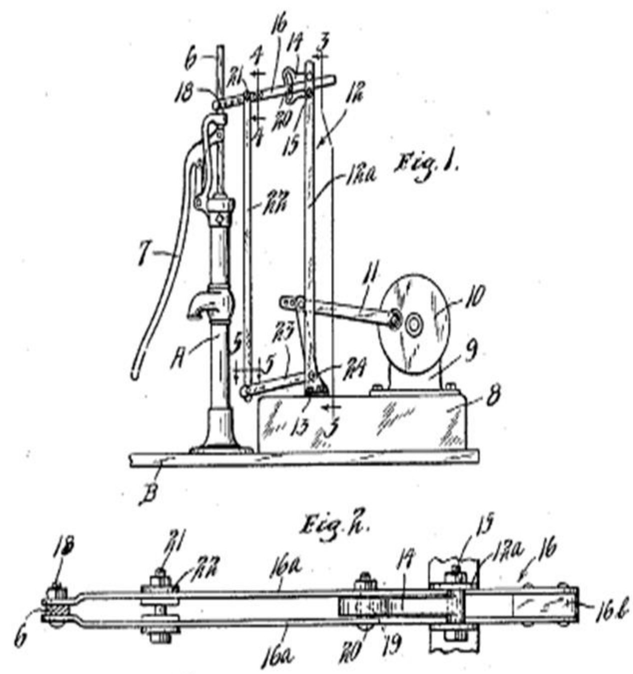


Figure 2: Rotational Motion System

Meeting with Water4

Meeting with the Water4 Foundation provided some clarity for how they wanted the system designed. Water4's goal was to be given design a pump jack that would be accessible by handicap and young children in Africa, a nation that is desperate for a clean water supply. Another standard the company set was for the force needed to lift the pump jack to be limited to 20 lbs. The design of the pump jack was to be purely mechanical to a point where the system could be built or prepared in the setting is was being applied. Water4 wanted the pump jack to match the stroke of the pump, which pumps water on the down stroke. The system needs to be simple and easily installed so the locals will be able to operate independently and efficiently to obtain clean water.

Initial Parameters

- Materials must cost less than $150
- Must be able to be built and repaired with materials and tools on hand
- Must be anchored to a 3 foot diameter concrete pad
- Desired flow rate of 4 GPM
- Pump operates best on 12 inch stroke
- Must be capable of being operated by disabled individuals and young children

Deliverables

- Working Prototype
- Test Stand
- Instructions for Assembly
- Bill of Materials
- Drawings
- SolidWorks Parts and Assemblies
- Recommendations for Future Improvement
- How it may be possible to attach a electrical pump in the future

Common Pumps and Water4's Current Pump Design

The India Mark II is a common pump found in many of the areas that Water4 works in. The problem with this pump is that a few of the components are complex, difficult to find, and expensive. Water4 is attempting to replace this pump with their own pump as seen in Figure 4. The Water4 pump is a durable pump that yields a flow rate of 4 GPM. One issue with this pump is that the operator will tend to pump in an oval shaped pattern, causing pre-mature wear on the bushing.

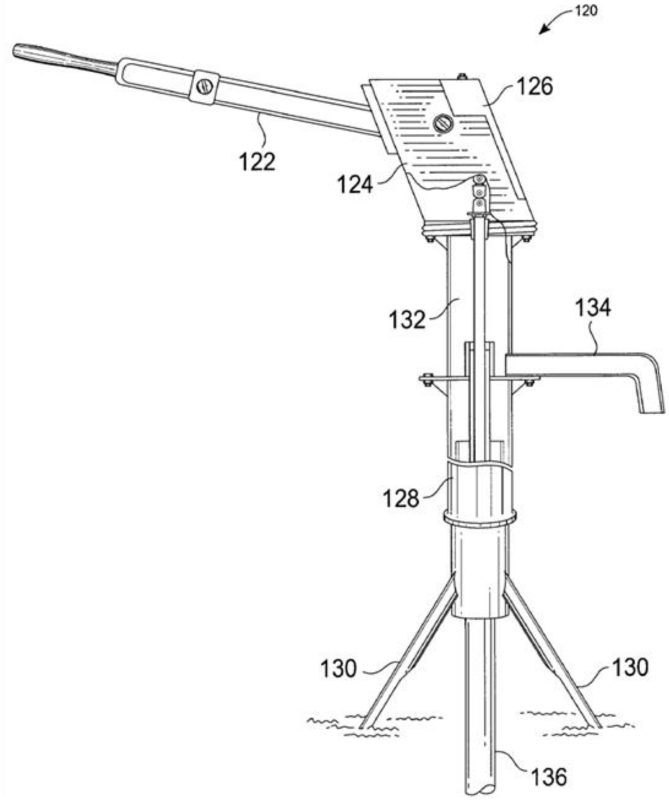


Figure 3: Water4's Current Pump **Figure 4: India Mark II**

Researching Alternative Pump Compatibilities

There are many different types of pumps used to access water in underdeveloped countries around the world. The treadle pump is a common pump found in these countries. It achieves a flow rate of 15.9 GPM mainly because it is operated by the operator's feet. However, the conflict with this specific design was that some disabled individuals that could not walk would not be able to operate the pump; therefore the design was not considered. The table below illustrates the flow rate comparisons between the treadle pump, India Mark II, and Water4's current pump design.

Table 1: Pump Comparisons (Modified for Water4)

Name	Type	Capacity (gal/min)	Corrosion Resistant	Village Level Operation and Maintenance	Location of Origin or Successful Use
Swiss Pedal	Suction-treadle	15.9	Yes	Yes	Cambodia
India Mark II	Piston	3.17	No	No	India
Water4 Pump	Piston	4.0	Yes	Yes	Africa

Accessibility because of the Pump Jack

Accessibility is improved by the pump jack by extending the lever off of the concrete pad. This allows individuals to access the pump without having to climb onto the concrete pad which they may be unable to do. The system also reduces the required force to work the pump by slightly increasing the length of the stroke.

Determining a Solution

Most patents that pertained to the project had expired in the early 1900s, eliminating any potential design conflicts. Several possible designs were researched and their components were examined. Alternative ways to power the pump jack were discussed, such as a bicycle attachment, which would be mainly used by healthy individuals. One of the potential designs is a simple lever pump that uses a connecting rod from a lever to a connector on the pump rod. The connector also acts as a weight to offset the required force to operate the pump. After discussing these potential designs, we decided to implement a simple A-frame design that would be anchored to the 3 foot diameter concrete pad. Connected to the frame would be a simple lever, using linear action to move the horse's head up and down vertically. With each pump the horse's head's radial motion would be converted to a 12 inch linear stroke and would in turn operate the pump down hole. A weight system will be implemented on this design. The rack connected to the pump rod would act as a partial weight. Images of the designs are illustrated below.

Initial Designs

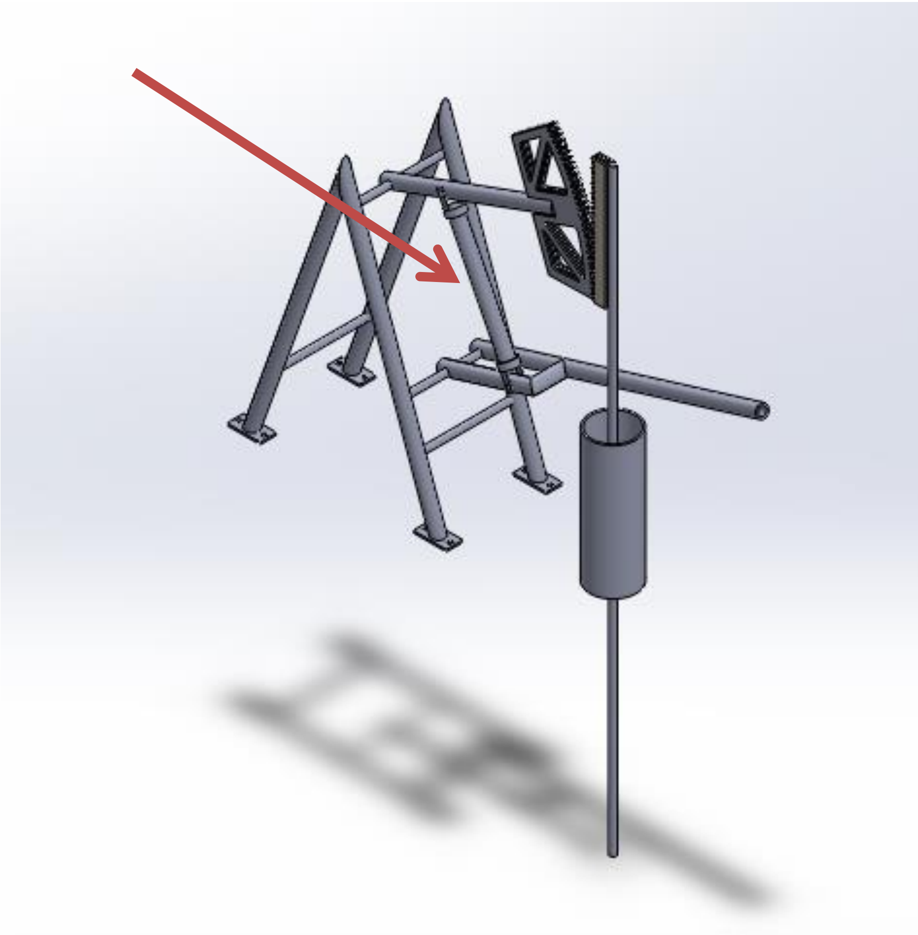


Figure 5: Initial Design

Figure 1 was the initial design using a simple A-frame and a connecting rod between the lever arm and horse's head. The horse's head mates with the rack and will force it down on the down stroke, hence pumping on the down stroke. It was determined that the connecting rod (shown in Figure 5) limited the travel of the system, the design was then tabled.

Figure 6: First Prototype

The concepts from the initial design were carried over to the first prototype design. The connecting rod was redesigned. Two connecting rods and bolts positioned in double shear were used to connect the lever arm and horse’s head. It was found that the newly designed connecting rod no longer limited the travel of the system.

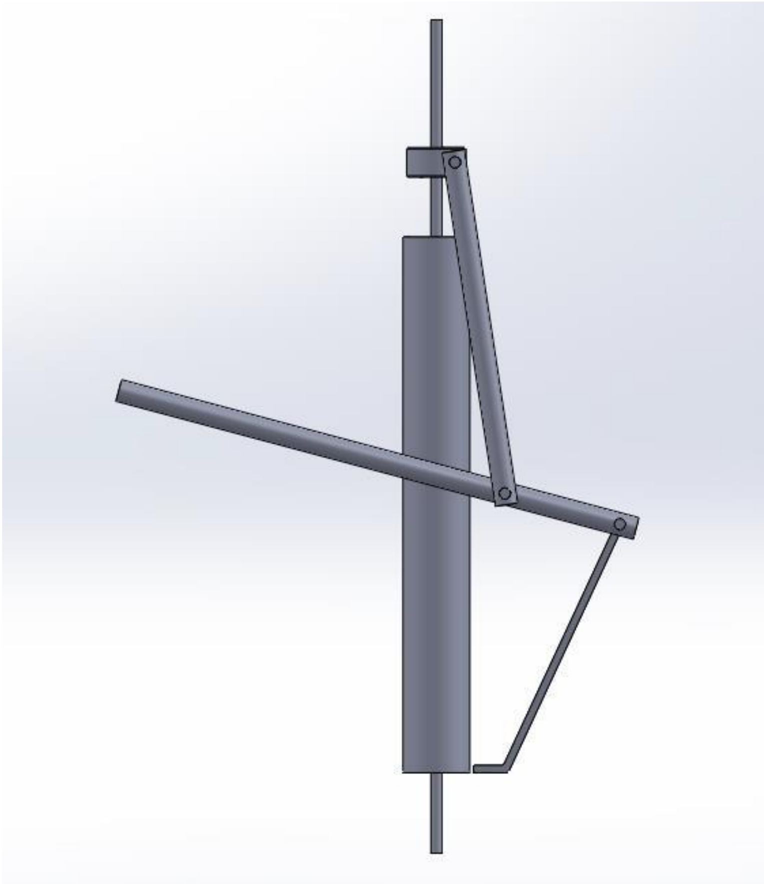


Figure 7: Alternative Design

Figure 7 was the alternative design for the system that used a simple lever action and had weights on the top of the rod to assist with the down stroke. One problem with this design was that it was not entirely accessible to disabled individuals and would be too difficult to pump on the down stroke. This design was not considered.

Prototype 1

The design in Figure 8 was modified from the A-frame to a square frame to reduce machining difficulty and possible safety hazards. A cut list and drawings was given to the Biosystems Lab technicians to cut the metal and construct the pump jack. The horse's head was cut out using the plasma table available in the shop. After Prototype 1 was constructed, it was taken to Water4's site in Oklahoma City, where it was presented to the client. The client found that the prototype was too heavy and wanted the frame and material size reduced.

Figure 8: Prototype 1 Side View

Prototype 2

To reduce the weight and frame size, the 2” square tubing was reduced to 1.5” square tubing. In addition to reducing the tubing size, the client suggested that the number of plates in the horse’s head be reduced and add a captured gear to prevent lateral movement. A counter balance system was also added on the back of the lever arm to provide a more balanced system when operated. It was found that after the new horses’ head was built, the plasma table provide enough precision to use an interior gear so it was removed, which allowed the center plate to protrude in between the pieces of the rack. The teeth were then cut from the center plate on the rack so that they would not interfere with the motion as shown in Figure 10.

Figure 9: Horse’s Head and Rack Mesh for Prototype 2

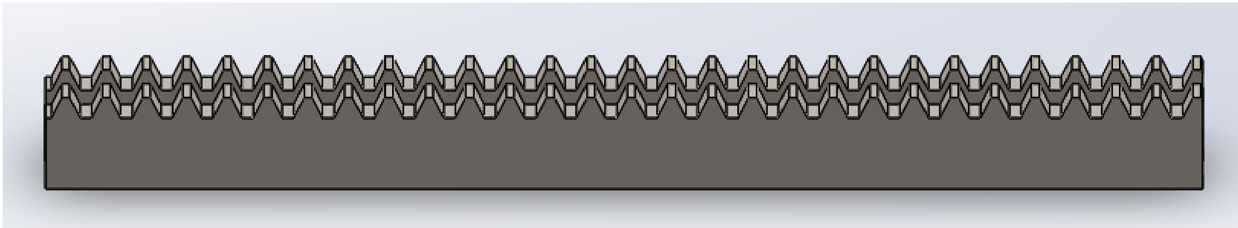


Figure 10: Rack with Center Teeth Removed

Figure 11: Prototype 2 Side View

Theory

The equations for the calculations performed to determine if the designs were feasible are illustrated below.

$$F_1 D_1 = F_2 D_2 \qquad \text{Eq. 1}$$

Lever Arm Deflection

$$\delta = -\frac{\mathrm{F}l^3}{3EI} \qquad \text{Eq. 2}$$

Where:

- F: Force (lb_f)
- l, D : Length (in)
- E: Modulus of Elasticity (psi)
- I: Moment of Inertia (in^4)
- δ: Deflection (in)

Calculations

The following solutions were calculated to determine the force required on the down stroke and the mechanical advantage for the lever arm and the overall system. A force of 40 lbs (F_1) was provided by Water4 as the force required for operating their current pump on the down stroke. Water4 also provided a stroke length of 12 inches (D_1) as the optimal stroke length to operate the pump.

Lever Arm Mechanical Advantage

$F_1 = 40\ lb_f$ $D_1 = 12.0”$ $D_2 = 26.5”$

$F_2 = 18.1\ lb_f$

$F_1 / F_2 =$ **2.2 Mechanical Advantage**

Overall Mechanical Advantage with Counterbalance

Down stroke:

$F_1 = 40\ lb_f$ $F_2 = 12\ lb_f$

$F_1 / F_2 =$ **3.3 Mechanical Advantage**

Upstroke:

$F_1 = 22\ lb_f$ $F_2 = 13\ lb_f$

$F_1 / F_2 =$ **1.7:1 Mechanical Advantage**

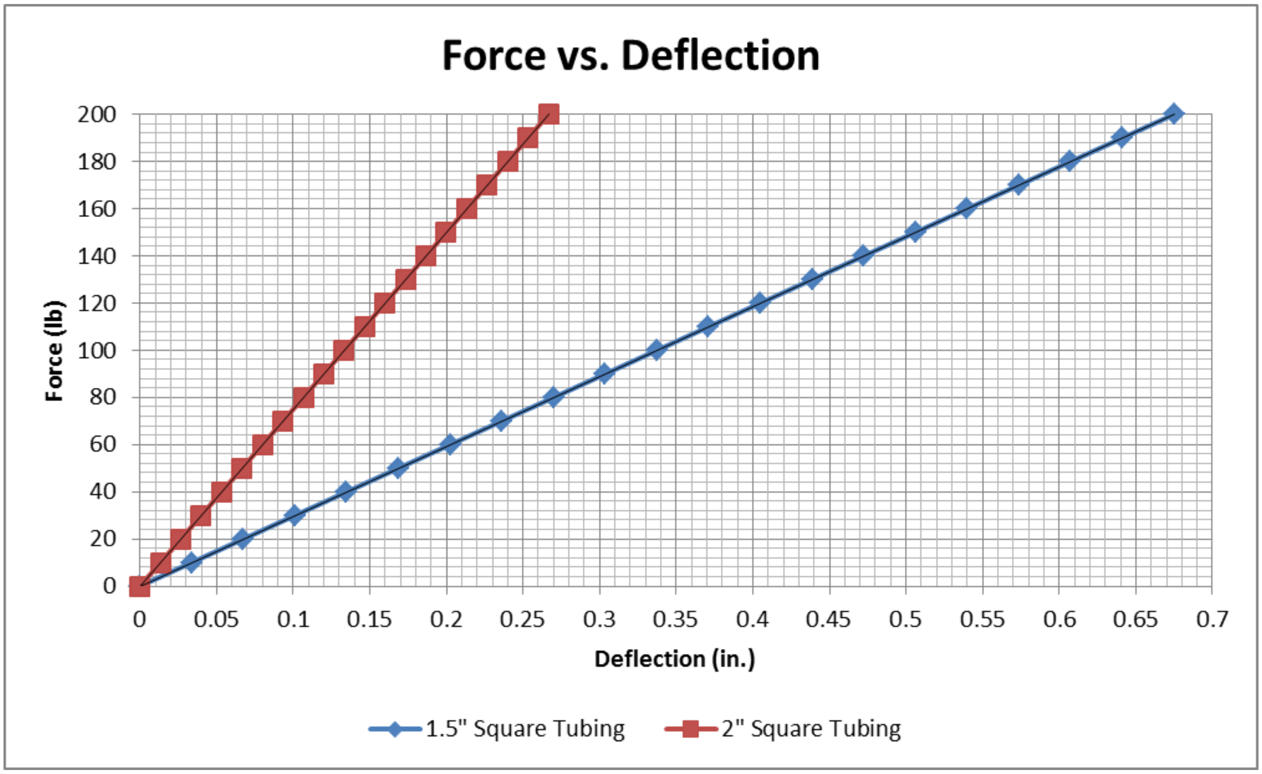


Figure 12: Force vs. Deflection Graph

Discussion of Results

The secondary force acting on the lever arm was found to be 18.1 lb_f. Using this value, the ratio of the forces acting on the lever arm was calculated, resulting in a 2.2:1 mechanical advantage for the lever arm. Figure 12 illustrates a comparison of the 2" square tubing vs. the 1.5" square tubing. The 2" square tubing could withstand approximately three times the force than the 1.5" square tubing when measuring deflection on the lever arm. At a force of 200 lb_f, To simulate an 80 feet of PVC pipe for the standard 80 foot wells, a weight of 16 lbs. was used on the lever arm, using the standard 1lb/5ft of PVC pipe. To achieve a 2:1 overall mechanical advantage, a counterbalance of 29 lbs. was placed on the opposite side of the lever arm to act as a counterbalance. This resulted in a 3.3 mechanical advantage for the down stroke and a 1.7:1 mechanical advantage for the upstroke. Figure 13 illustrates how the system reacted with each counterbalance. The optimal counterbalance combination was an upstroke of 13 lb_f and a down stroke of 12 lb_f. This combination was optimal because the system was the most balanced.

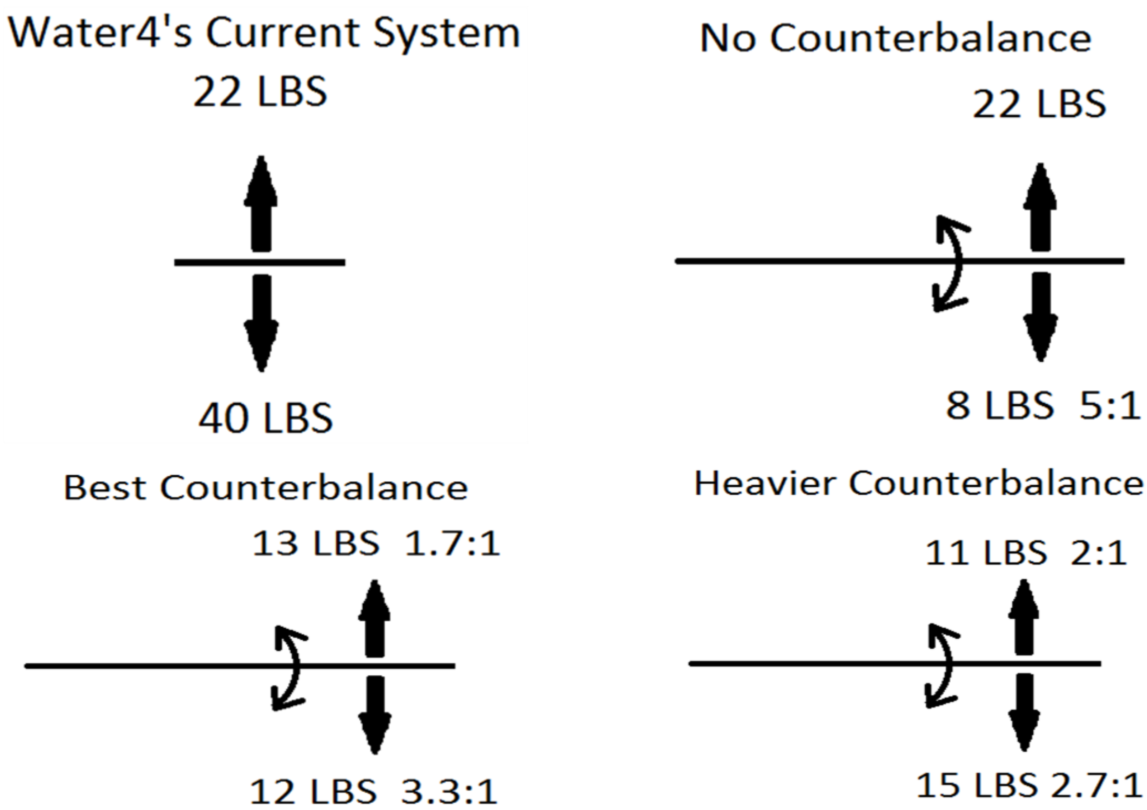


Figure 13: Counterbalance Comparisons

Prototype 1 vs. Prototype 2

Table 2

Parts List								
Material	**1/4" plate steel**	**1.5" Square Tubing**	**2"x2" Square Tubing**	**Sleeve Bearings**	**3/4 Hot Rolled Round Stock**	**Washers**	**Cotter Pins**	**Galvanized Nipple**
Quantity	2.5'x2'	28'	28'	18	3.5'	18	14	18"
Weight		2.252 lb/ft	3.05 lb/ft	0.045 lb/ea	1.502 lb/ft	0.043 lb/ea	0.0045 lb/ea	1.13 lb/ft
Price per Unit	$50 per 1/4 sheet	$1.68 per ft	$2.20 per ft	$2.21 each	$0.95 per ft	$0.23 each	$0.34 each	$7.54 each
Price of Material	$31.25	$47.04	$61.60	$39.78	$3.33	$4.14	$4.76	$7.54

Table 3

Weight Calculations	Weight (lbs)	
	Prototype 1	Prototype 2
Horse's Head	15.5	8.4
Rack	6.2	4.6
Square Tubing	85.4	63.1
Sleeve Bearings	0.8	0.9
Round Stock	5.3	6.8
Washers	0.8	0.7
Cotter Pins	0.06	0.05
Galvanized Nipple	1.7	1.7
Roller	1.5	1.5
Roller Mounting Plates	2	2
Total	119.26	89.75

Table 4

Budget			
Prototype 1		Prototype 2	
1/4" plate steel	$50.00	1/4" plate steel	$31.25
2" Square Tubing	$61.60	1.5" Square Tubing	$47.04
Sleeve Bearings	$44.20	Sleeve Bearings	$44.20
Pins 3/4 hot rolled round stock	$4.75	Pins 3/4 hot rolled round stock	$4.28
Washers	$4.60	Washers	$4.60
Cotter Pins	$5.10	Cotter Pins	$5.10
Galvanized Nipple	$7.54	Galvanized Nipple	$7.54
1" pipe	$0.17	1" pipe	$0.17
Total	$177.96	Total	$144.18

Estimated Budget vs. Actual Budget

Table 5

Budget			
Estimated Budget		Prototype 2	
1/4" plate steel	$50.00	1/4" plate steel	$31.25
2" Square Tubing	$61.60	1.5" Square Tubing	$47.04
Galvanized Nipple	$7.54	Sleeve Bearings	$44.20
Misc. Materials	$30.00	Pins 3/4 hot rolled round stock	$4.28
		Washers	$4.60
		Cotter Pins	$5.10
		Galvanized Nipple	$7.54
		1" pipe	$0.17
Total	$149.14	Total	$144.18

Testing Prototype 2

To test the pump jack system properly, the system would need to be simulated for approximately three to four weeks of general use. A testing platform was designed that uses an electric motor to operate the system continuously as seen in Figure 12. The system was tested for an accumulated 24 hours on several different days and achieved an average of 5 GPM when on its highest setting. Since no flaws or failures were observed during the testing period, it was concluded that the system would operate properly when correctly installed. A flow rate of 5 GPM was achieved when testing with a smaller individual manually to simulate a child operating the system. A maximum flow rate of 8 GPM was achieved when the system was operated rapidly.

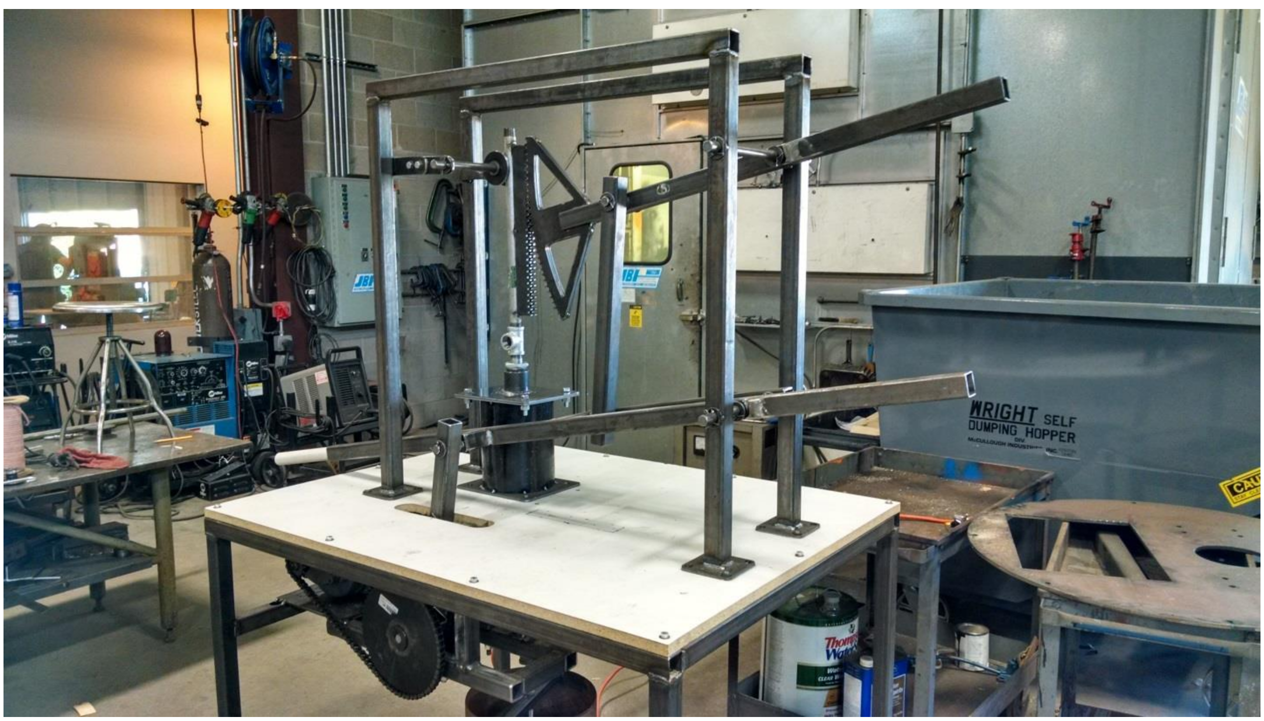


Figure 14: Test Stand with Electric Motor

Conclusion

After the reduction of size and weight of the system, Prototype 2 proved to be more of an economical choice. Prototype 1 was over the project budget by $27.96 whereas Prototype 2 was under budget by $5.82. In terms of transportation, cost, and weight, Prototype 2 is the optimal selection. Further testing would be needed to determine if Prototype 2 would be able to operate on a well deeper than 80 feet, although it is hypothesized that it would be operable at 100 feet. The counterbalance chosen resulted in a 3.3:1 ratio on the down stroke and a 1.7:1 ratio on the upstroke. While the upstroke mechanical advantage did not meet the desired 2:1 ratio, it is believed that this combination provides the most balanced system.

Recommendations

According to the testing results, the system will operate with balance when it is properly installed on Water4's water pump. Painting the system is recommended to reduce corrosion. Periodically applying lubricants where the horse's head and the rack mesh will also extend the system's life, preventing wear and corrosion due to the environment. One improvement for the design would be to make the horses' head bolt on; further testing would be needed to see if this is a viable option. A bolt on horses' head would allow for easy replacement if the part failed due to wear

Acknowledgements

Wayne Kiner and the BAE Staff – Constructing the prototype

Dr. Marvin Stone – Advisement with the design process

Dr. Paul Weckler – Advisement throughout the design and construction process.

Steve Stewart – Inventor of Water4 System and primary contact

Dr. Daniel Thomas – Providing transportation to Water4

Appendices

Table 1: Stewart, E. (2003). How to select the proper human-powered pump for potable water. In D. o. C. a. E. Engineering (Ed.), *CE 5993 Field Engineering in the Developing World*. Michigan: Michigan Technological University. Available at www.cee.mtu.edu.

Table 6 - Task Lists

Task Mode	Task Name	Duration	Start	Finish	Resource Names
Manually Scheduled	Preliminary Design	16 days	Mon 1/13/14	Mon 2/3/14	Ryan, Russell
Manually Scheduled	Make a Cut List	2 days	Mon 2/3/14	Tue 2/4/14	Russell
Manually Scheduled	Build Website	28 days	Wed 2/5/14	Fri 3/14/14	Luke
Manually Scheduled	Get Weckler's Approval of List	1 day	Wed 2/5/14	Wed 2/5/14	Matt
Manually Scheduled	Order Material	5 days	Thu 2/6/14	Wed 2/12/14	Russell
Manually Scheduled	Build Prototype	10 days	Thu 2/13/14	Wed 2/26/14	BAE Shop
Manually Scheduled	1st Rough Draft of Report	21 days	Mon 2/10/14	Mon 3/10/14	Luke, Matt
Manually Scheduled	Email Client About Progress	1 day	Thu 3/6/14	Thu 3/6/14	Luke
Manually Scheduled	Present Prototype to Client	1 day	Wed 3/12/14	Wed 3/12/14	Group

Manually Scheduled	2nd Draft of Report	4 days	Tue 3/11/14	Fri 3/14/14	Luke, Matt
Manually Scheduled	Revise Prototype	3 days	Mon 3/24/14	Wed 3/26/14	Ryan, Russell
Manually Scheduled	Finalize Prototype	11 days	Fri 3/28/14	Fri 4/11/14	Ryan
Manually Scheduled	Finalize Report	11 days	Mon 3/31/14	Mon 4/14/14	Luke, Matt
Manually Scheduled	Edit Presentation	6 days	Mon 3/24/14	Mon 3/31/14	Group
Manually Scheduled	Finalize Presentation	7 days	Tue 4/1/14	Wed 4/9/14	Group
Manually Scheduled	Presentation to Client	1 day	Thu 5/1/14	Thu 5/1/14	Group

Cut List

Cut List		
Qty	**Description**	**Length (in)**
	Material 1.5" Square Tubing	
4	Legs	34.50"
1	Beam	30.00"
2	Top Bar	36.00"
1	Lever	48.00"
1	Center Lever *	20.00"
1	Lever Cross Brace *	5.25"
1	Upright Members	22.00"
	Material .75" HR Round Stock	
2	Main Cross Bar	13.00"
2	Upright Cross Bar	4.75"
	Material .25" Plate Steel	
2	Horse's Head Gear**	
1	Horse's Head Center**	
2	Rack Gear**	
1	Rack Center**	
4	Mounting Plate**	
2	Roller Sides**	
2	Roller Mounting Plate Roller Side**	
2	Roller Mounting Plate Leg Side**	
	Material 1" Pipe	
1	Roller Center	1.30"
	*** 45˚ cut on one end measurement listed is on the long side of angle**	
	**** Reference Appendices for Drawing(s)**	

Parts List

Parts List		
Qty	**Name**	**Size**
1	Horse's Head	**Refer to Cut List**
1	Rack	
4	Legs	
1	Beam	
2	Top Bar	
1	Lever	
1	Center Lever	
1	Lever Cross Brace	
1	Upright Member	
2	Main Cross Bar	
2	Roller Sides	
2	Roller Mounting Plate Roller Side	
2	Roller Mounting Plate Leg Side	
2	Upright Cross Bar	
18	Flanged Sleeve Bearings	1" OD; 0.75" ID
18	Washers	1.25" OD; 0.75" ID
14	Cotter Pins	1.25" L; 0.125" D
1	1" Pipe	1.30" L; 1.00" ID
1	.75" Galvanized Nipple	18" L; 0.75" ID

Drawings Attached: See Following Pages

The Pump Jack Advantage

Ryan Dunkerson
Matt Gengler
Luke Serner
Russell Staples

Sponsored by:

Water4 Foundation

WATER4'S MISSION STATEMENT

- Eradicate the world's water crisis.
- Water4 uses inexpensive materials and easily-transferable technology

- Training, equipping and supporting nationals to be the solution to their own community's water needs.

WATER4'S CURRENT SYSTEM

THE PUMP JACK ADVANTAGE MISSION STATEMENT

- System that can be used by handicapped people and small children without assistance from others
- Ensure it can be continually improved
- The go to system for all manually pumped water wells.

BACKGROUND

- 176 gallons/day vs. 5 gallon/day. [1]
- 37% of people on the African continent currently live in a water-scarce environment.[2]
- 115 people in Africa die every hour from poor sanitation, poor hygiene, and contaminated water.[3]
- ¼ of the population spends at least half an hour per trip to collect water.[3]

Water Scarcity Map of 2012

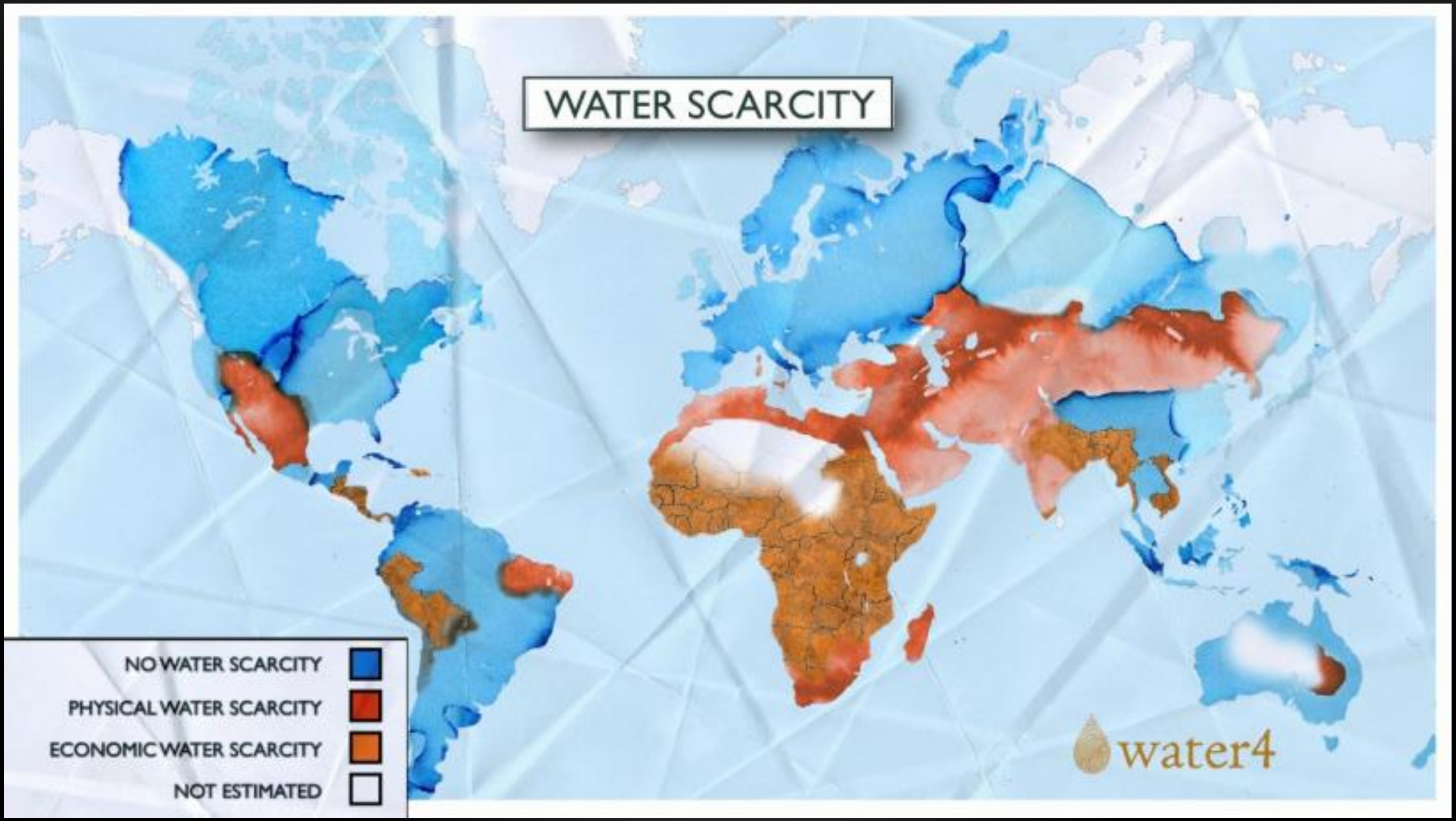


Figure 1

CONSTRUCTION OF SYSTEM

PROBLEM STATEMENT

- Build a pump jack with a mechanical advantage
- Pumps water on the downstroke
- Make pump system more accessible

PARAMETERS

- Materials must cost less than $150
- Must be able to be built and repaired with materials and tools in the region
- Anchored to a 3 foot diameter concrete pad
- A flow rate of 4 GPM or higher.

PARAMETERS CONTINUED

- Must be capable of being operated by handicap people and young children

- 2:1 mechanical advantage
  - Ex: Instead of requiring 40 lb_f, only 20 lb_f will be needed

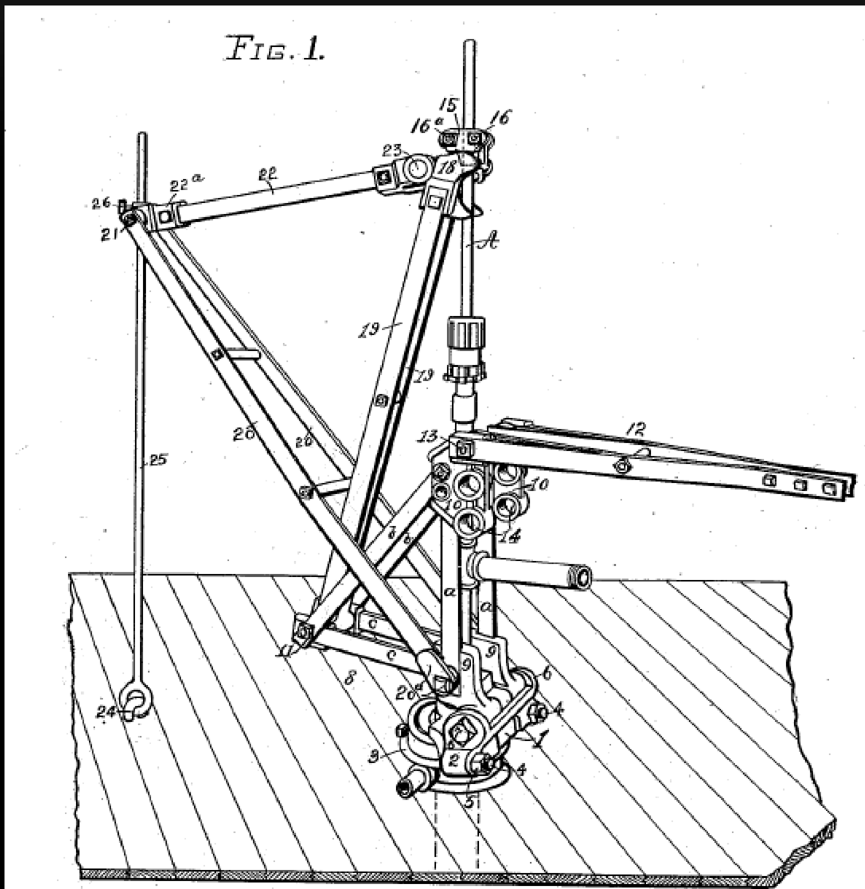
DELIVERABLES

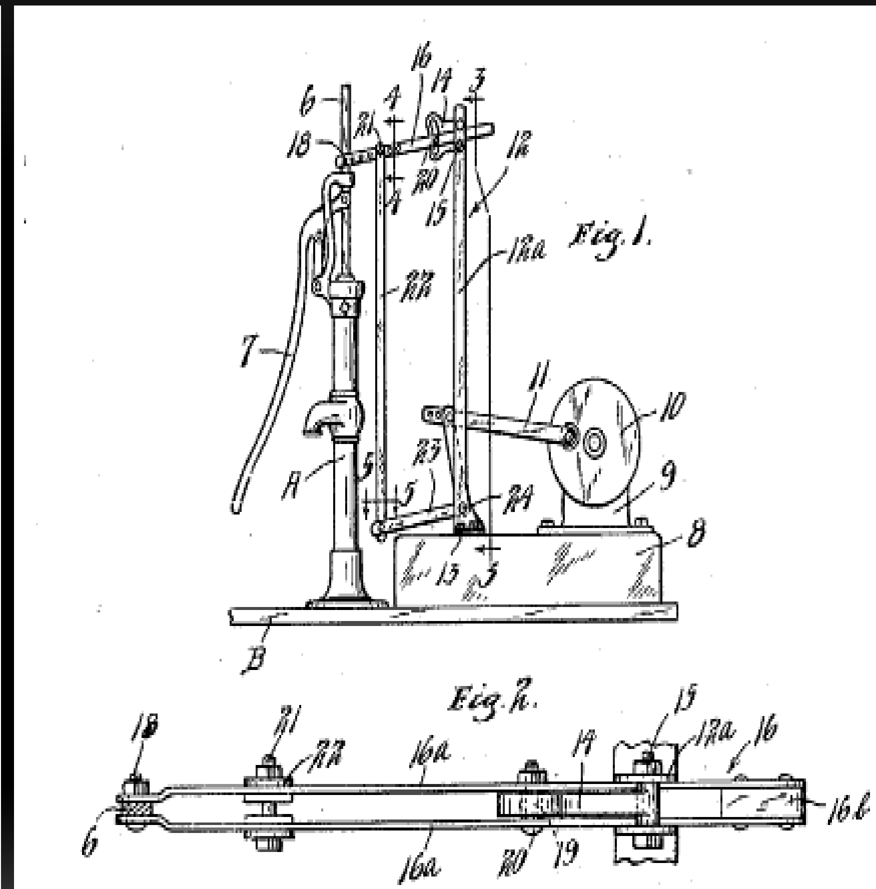
- Working Prototype
- Test Stand
- Instructions for Assembly
- Bill of Materials
- Drawings
- SolidWorks Parts and Assemblies
- Recommendations for Future Improvement

PATENTS

- Most mechanically advantaged pump jack patents had expired by early 1900s, eliminating possible design conflicts

INFLUENCES FROM PATENTS

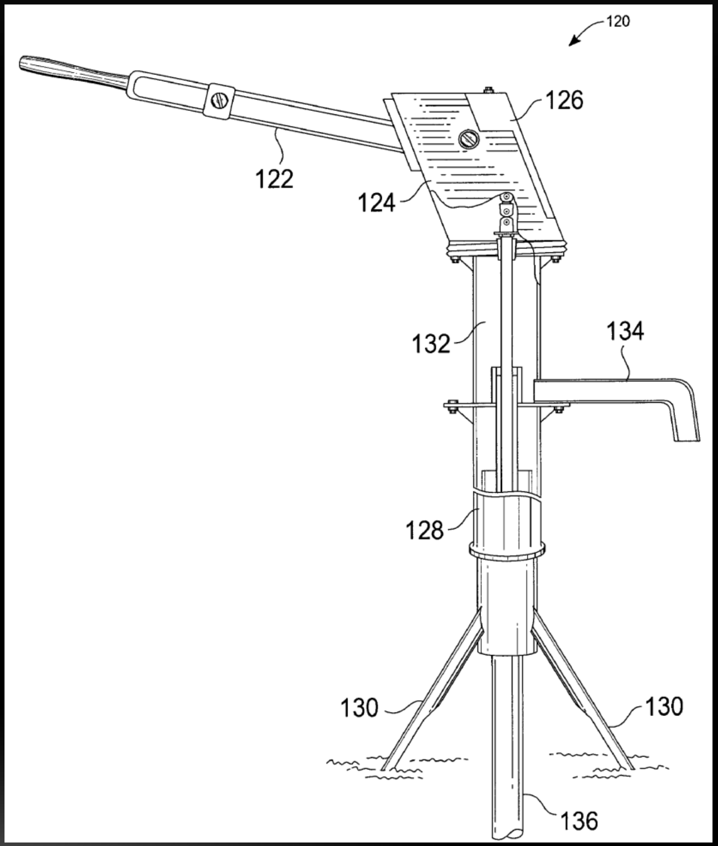




CURRENT PUMP DESIGN

Water4 Pump

India Mark II



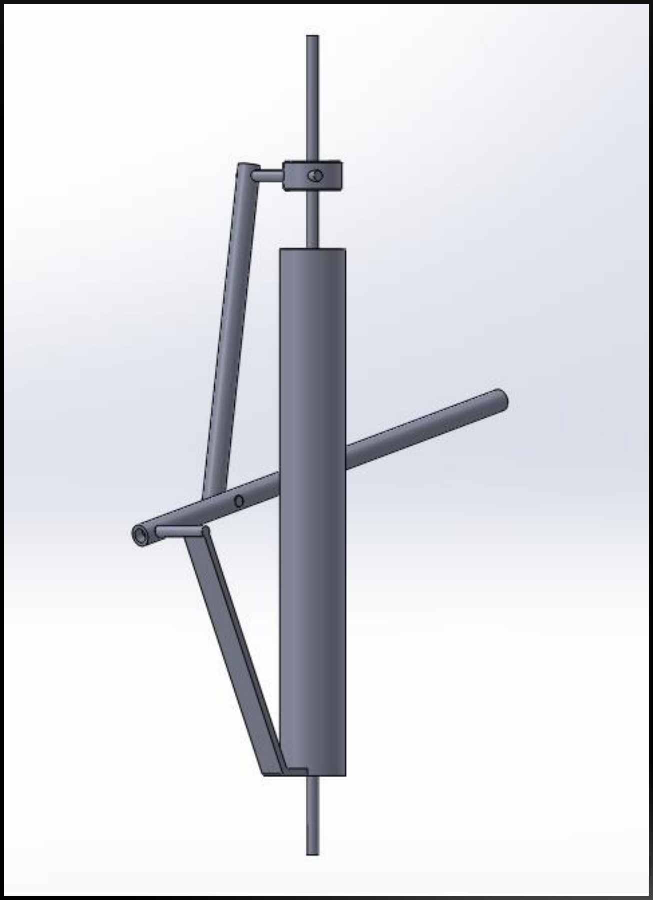
TREADLE PUMP EXAMPLE

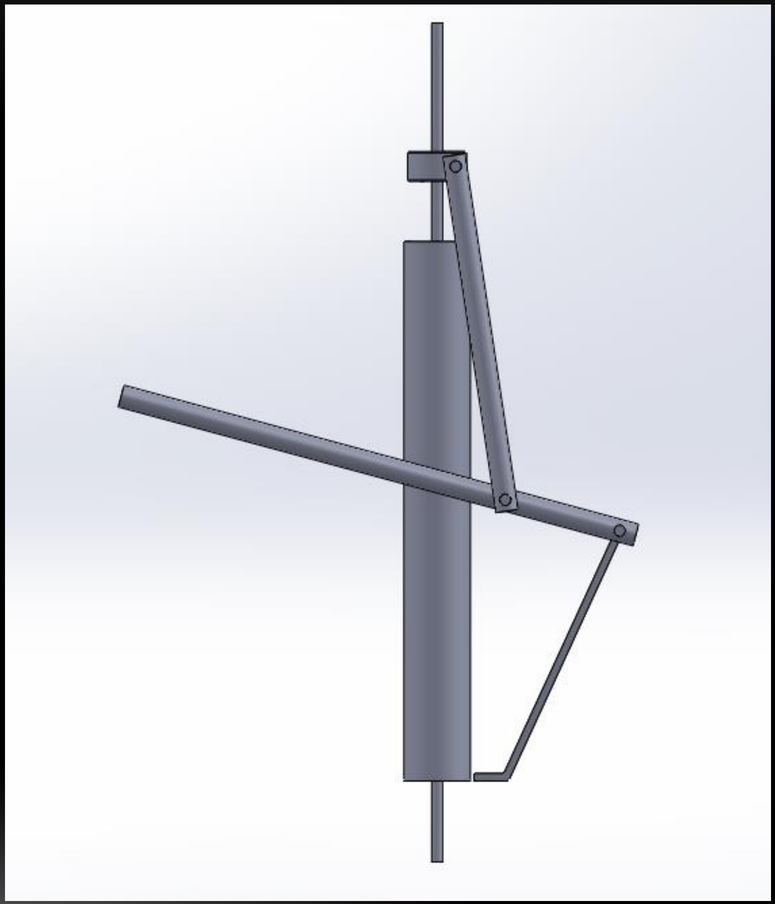
HUMAN POWERED PUMPS

Name	Type	Capacity (gal/min)	Corrosion Resistant	Village Level Operation and Maintenance	Location of Origin or Successful Use
Swiss Pedal	Suction-treadle	15.9	Yes	Yes	Cambodia
India Mark II	Piston	3.17	No	No	India
Water4 Pump	Piston	4.0	Yes	Yes	Africa

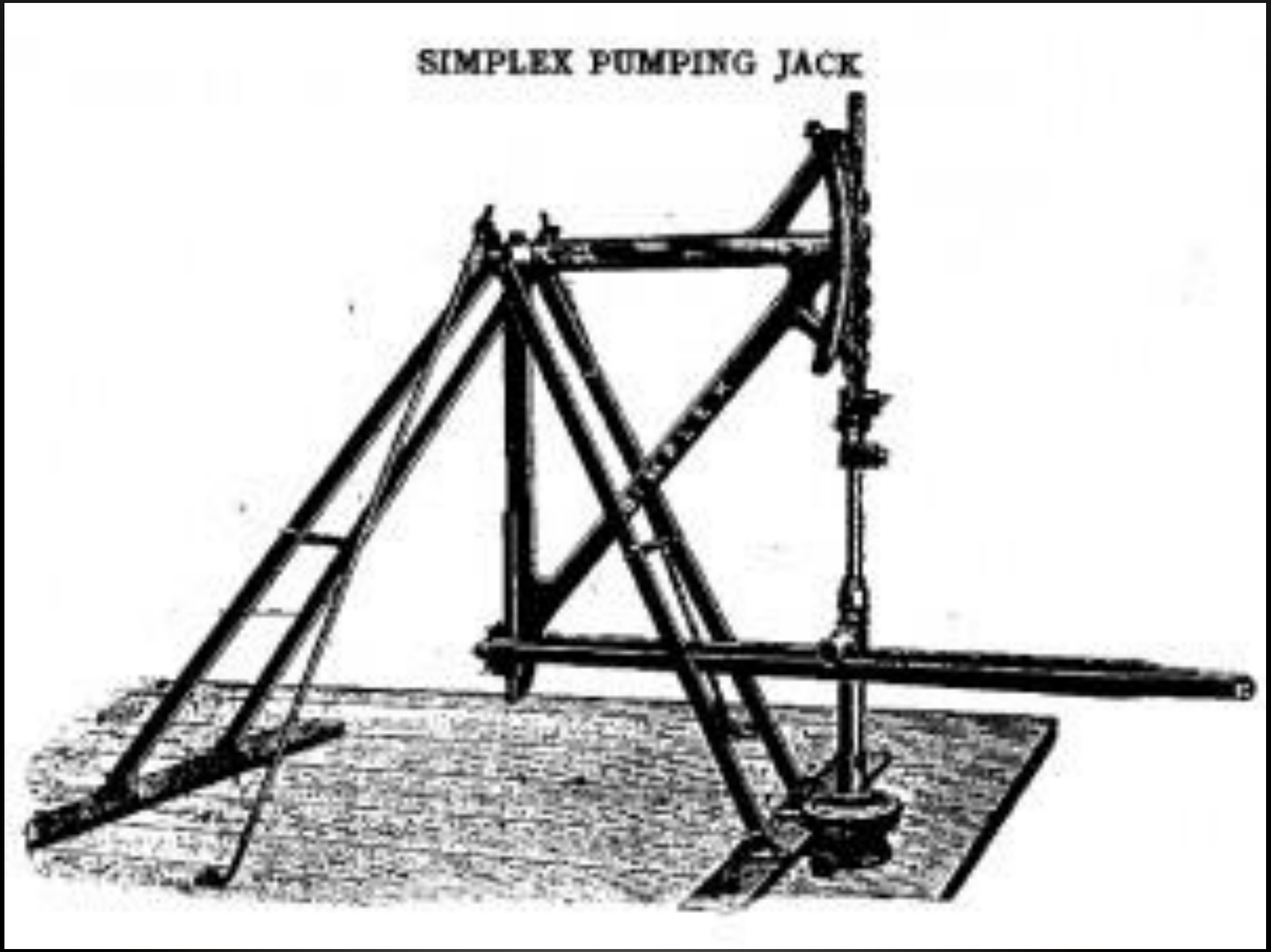
Table 1

ALTERNATIVE DESIGN

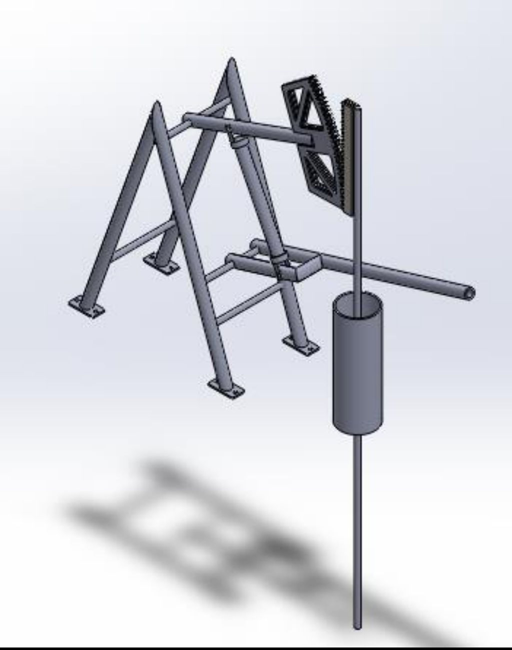


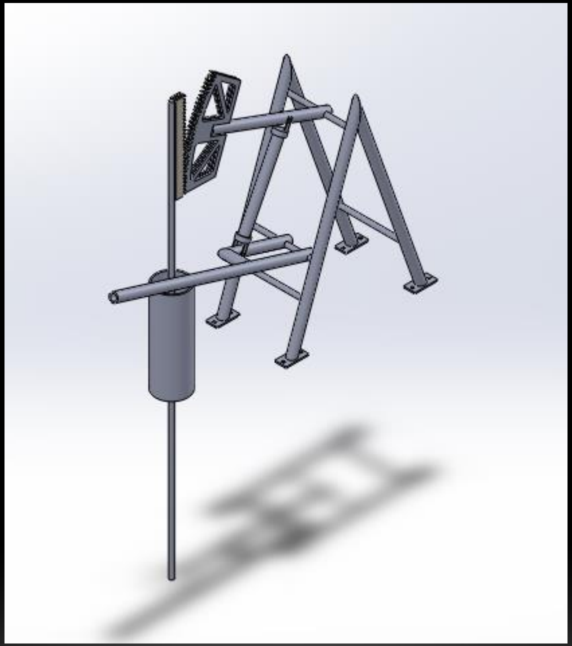


SIMPLE PUMP JACK MODEL



2ND ALTERNATIVE DESIGN

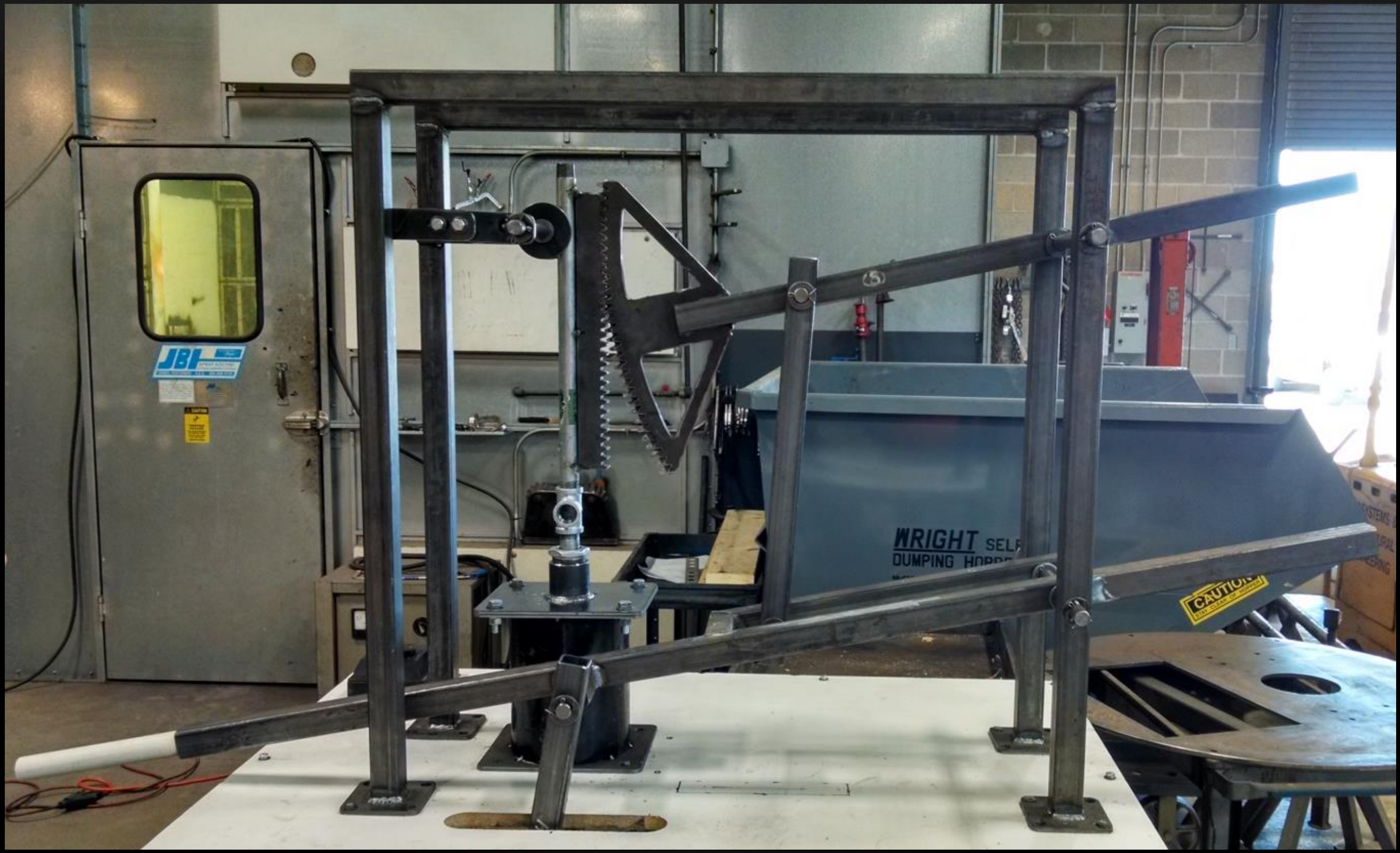




INITIAL DESIGN

FIRST PROTOTYPE

SECOND PROTOTYPE



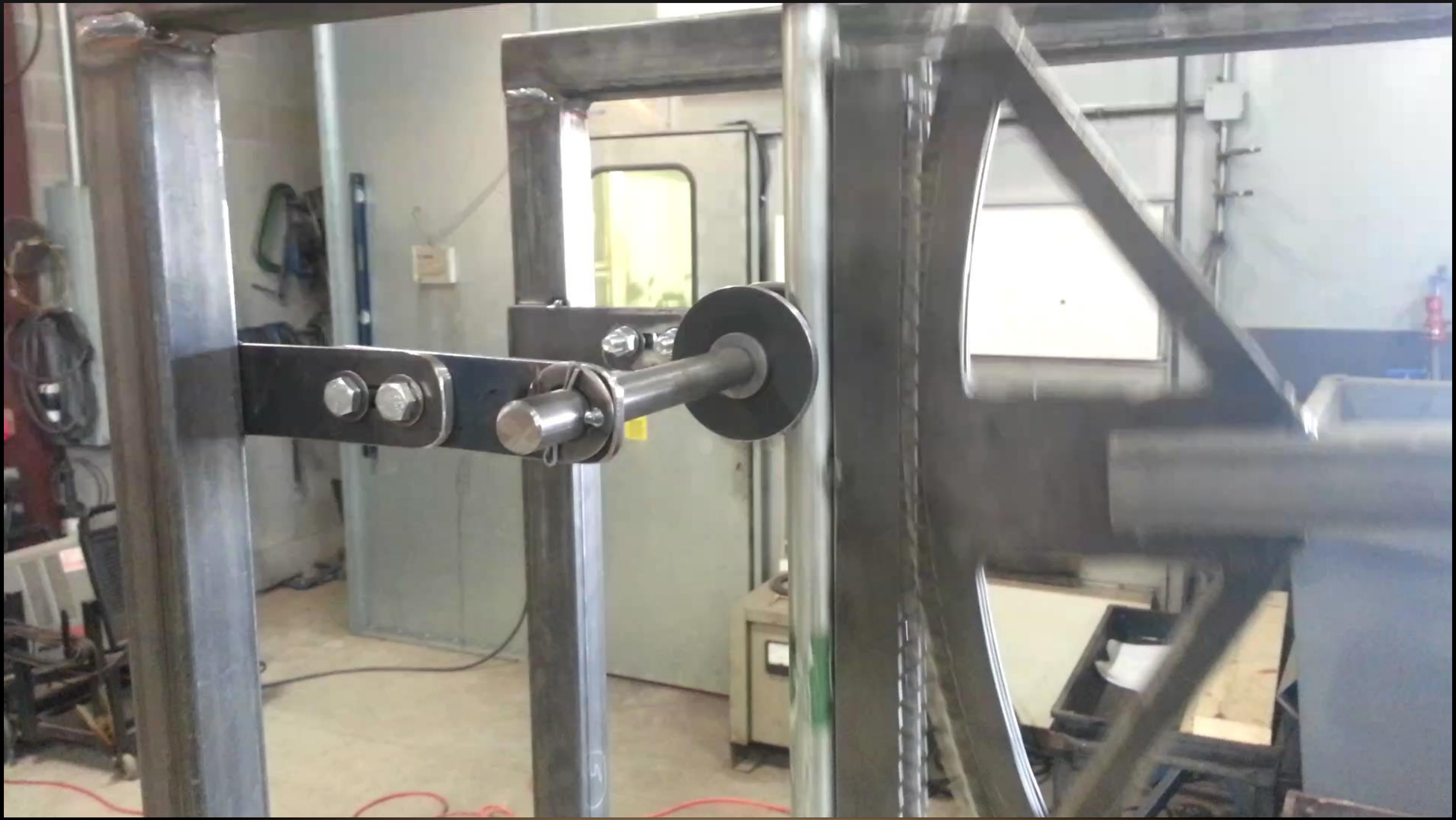
SECOND PROTOTYPE GEAR MESH

SECOND PROTOTYPE VERTICAL ROLLER

ALIGNING THE HORSE'S HEAD

TEST STAND DEMONSTRATION

PULLEY DEMONSTRATION



DEMONSTRATION

EQUATIONS

- $F_1 D_1 = F_2 D_2$
- $\frac{F_1}{F_2}$ = Ratio
- $\delta = \frac{Fl^3}{3EI}$

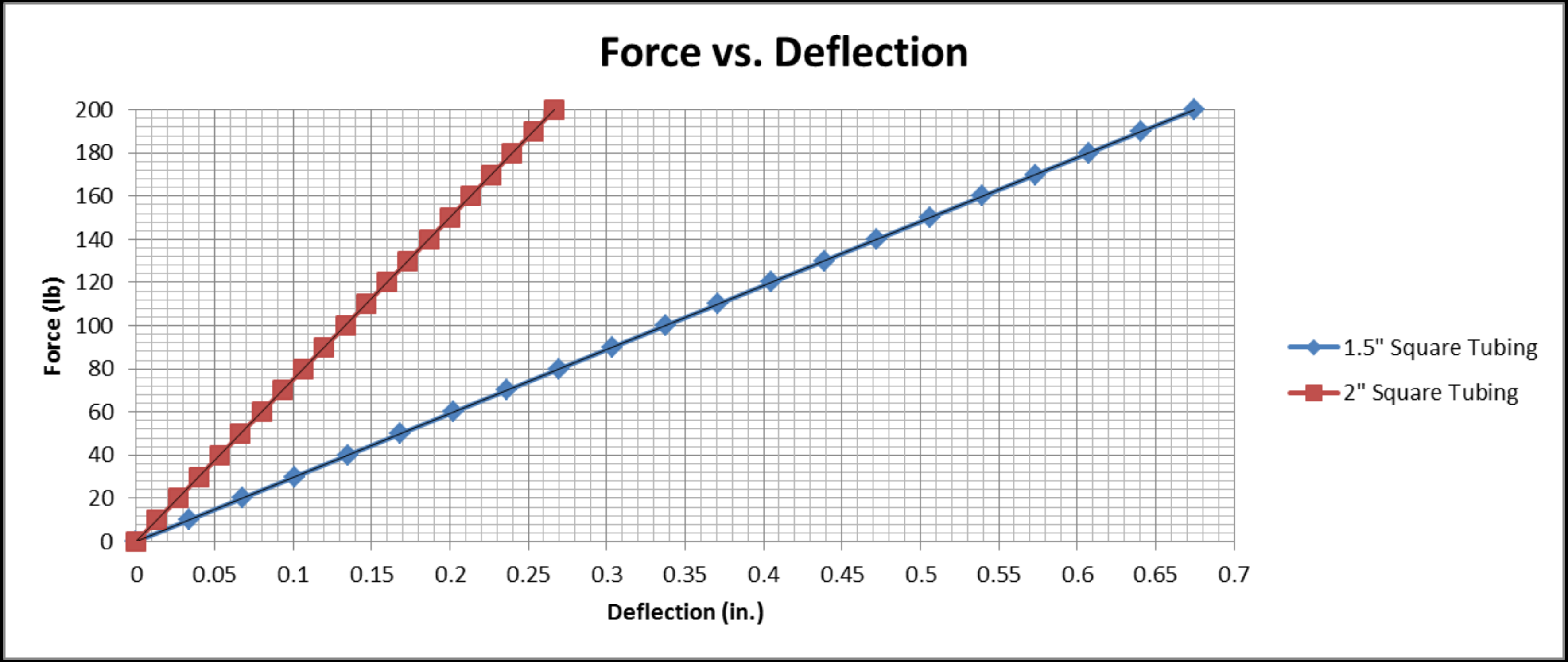
- F: Force (lb_f)
- l, D : Length (in)
- E: Modulus of Elasticity (psi)
- I: Moment of Inertia (in^4)
- δ: Deflection (in)

CALCULATIONS

- $F_1D_1 = F_2D_2$ For Lever Arm
  - Known Values $F_1 = 40\ lb_f$ $D_1 = 12.0''$ $D_2 = 26.5''$
  - $F_2 = 18.1\ lb_f$
  - $\frac{F_1}{F_2} = 2.2$
  - Mechanical Advantage of 2.2:1

CALCULATIONS CONTINUED

- $\delta = \frac{Fl^3}{3EI}$ For Lever Arm



WEIGHT CALCULATIONS

Weight Calculations	Weight (lbs)	
	Prototype 1	Prototype 2
Horse's Head	15.5	8.4
Rack	6.2	4.6
Square Tubing	85.4	63.1
Sleeve Bearings	0.8	0.9
Round Stock	5.3	6.8
Washers	0.8	0.7
Cotter Pins	0.06	0.05
Galvanized Nipple	1.7	1.7
Roller	1.5	1.5
Roller Mounting Plates	2	2
Total	119.26	89.75

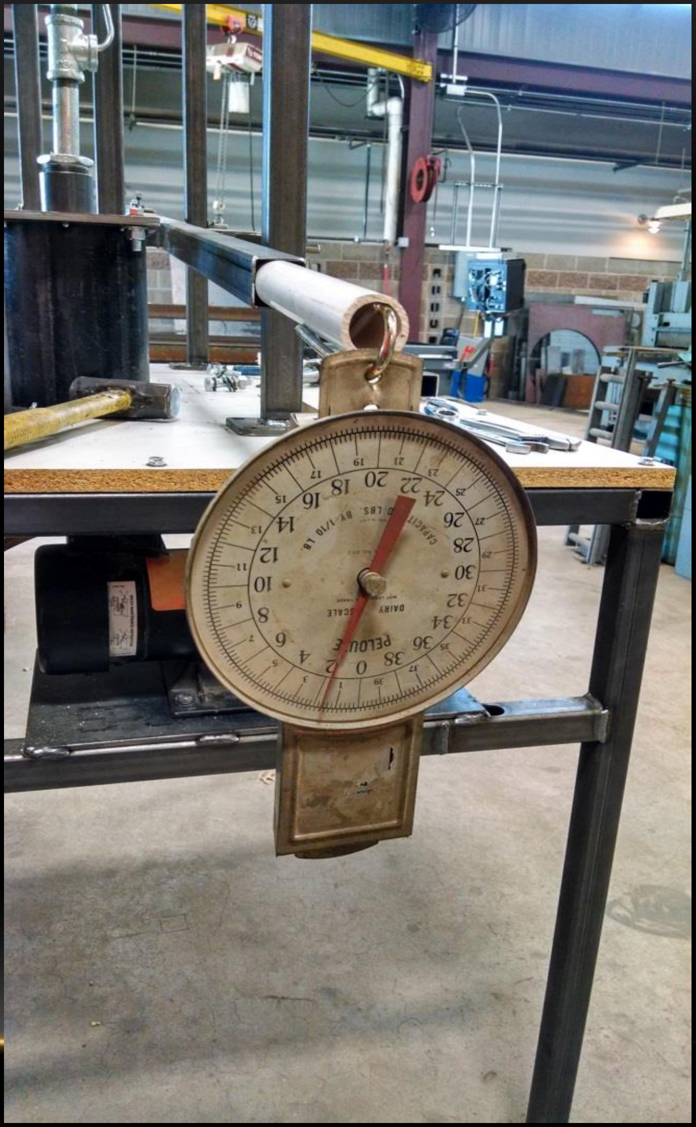
INITIAL BUDGET ESTIMATE

1/4" plate steel	$50.00
2" Square Tubing	$61.60
Galvanized Nipple	$7.54
Misc. Materials	$30.00
Total	$149.14

COST ANALYSIS

Prototype 1		Prototype 2	
1/4" plate steel	$50.00	1/4" plate steel	$31.25
2" Square Tubing	$61.60	1.5" Square Tubing	$47.04
Sleeve Bearings	$44.20	Sleeve Bearings	$44.20
Pins 3/4 hot rolled round stock	$4.75	Pins 3/4 hot rolled round stock	$4.28
Washers	$4.60	Washers	$4.60
Cotter Pins	$5.10	Cotter Pins	$5.10
Galvanized Nipple	$7.54	Galvanized Nipple	$7.54
1" pipe	$0.17	1" pipe	$0.17
Total	$177.96	Total	$144.18

TESTING



TESTING RESULTS

- After 24 hours of testing, system did not show significant wear and operated well when attached to the electric motor.
- The pulley system kept the rack aligned.

TESTING WITH COUNTERBALANCE

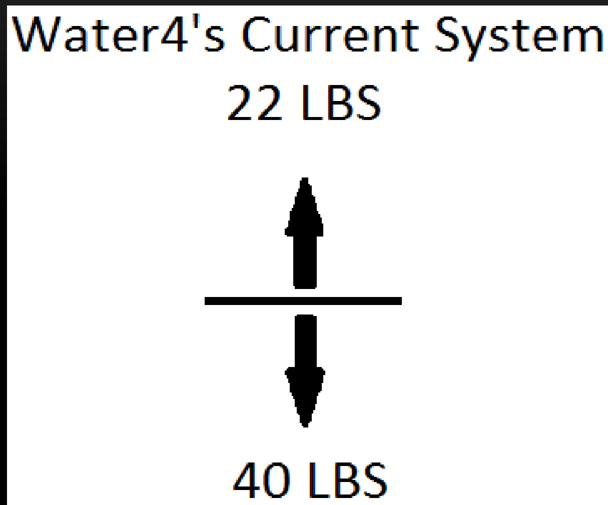
Downstroke:

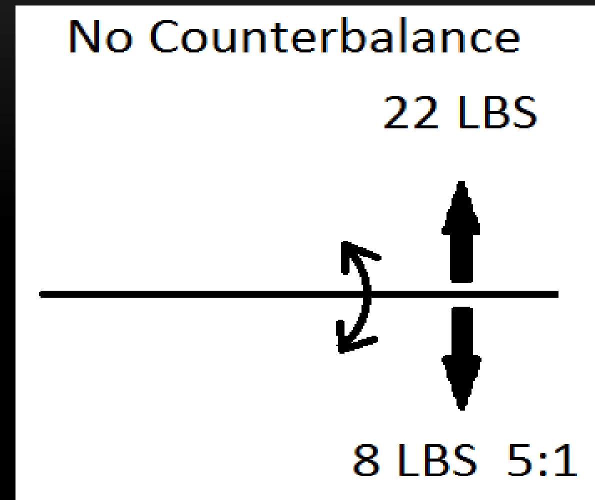
- F_1 = 40 lb_f F_2 = 12 lb_f $\frac{F_1}{F_2}$ = 3.3
- Mechanical Advantage of 3.3:1

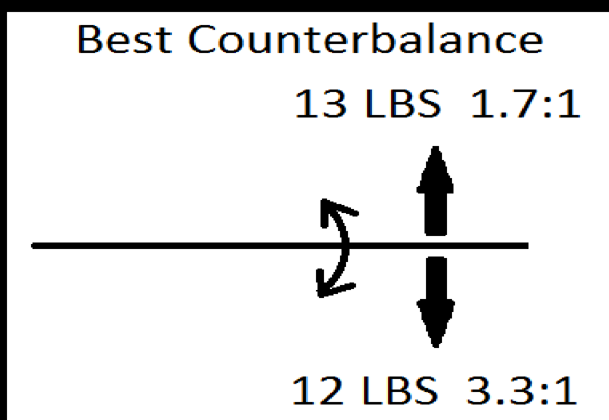
Upstroke:

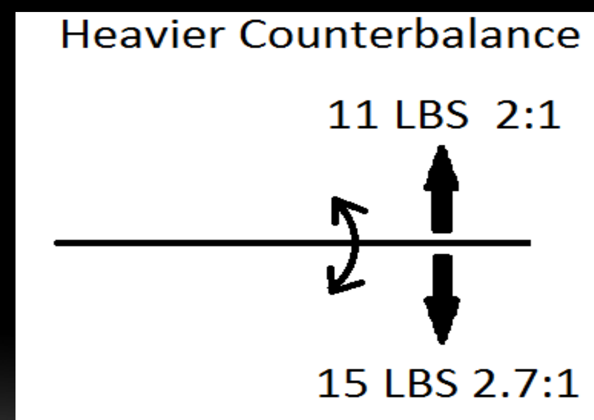
- F_1 = 22 lb_f F_2 = 13 lb_f $\frac{F_1}{F_2}$ = 1.7
- Mechanical Advantage of 1.7:1

COMPARISON OF RESULTS









CONCLUSION

- Design goals were achieved
- The 2:1 mechanical advantage for the downstroke was exceeded by a 3.3:1 ratio
- The 2:1 advantage can be met on the upstroke with counterbalance but it will require more down force
- Construction of design was completed under budget by $5.82
- We limited the stroke to 12 inches for optimum performance
- A flow rate of at least 5 GPM was maintained at 44 strokes/min
- Moves the pump handle off of the edge of the concrete pad

RECOMMENDATIONS

- Paint the system
- Lubrication
- Bolt on horse's head
- Wrap inner portion of the pulley with a piece of tire inner tube
- Further wear testing

ACKNOWLEDGEMENTS

- Wayne Kiner and the BAE Lab Staff
- Dr. Marvin Stone
- Steve Stewart (Inventor of Water4 System)
- Water4 Staff
- Dr. Paul Weckler
- Dr. Daniel Thomas

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QUESTIONS?

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